

APPLICATION

FOR UNITED STATES LETTERS PATENT

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT I, **Paul A. Knight**, a citizen of Canada, have invented a new and useful spray coolant reservoir system of which the following is a specification:

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Spray Coolant Reservoir System

CROSS REFERENCE TO RELATED APPLICATIONS

Not applicable to this application.

**STATEMENT REGARDING FEDERALLY
SPONSORED RESEARCH OR DEVELOPMENT**

Not applicable to this application.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to spray thermal management systems for thermally managing electronic devices and more specifically it relates to a spray coolant reservoir system for increasing the efficiency and performance of a spray thermal management system.

1 **Description of the Related Art**

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3 Modern electronic devices have increased thermal management requirements.
4 Conventional dry thermal management technology (e.g. fans, vents) simply is not
5 capable of efficiently cooling modern high-end electronics.

6

7 Spray thermal management technology is being adopted today as the most efficient
8 option for thermally managing electronic systems. United States Patent No. 5,220,804
9 entitled High Heat Flux Evaporative Spray Cooling to Tilton et al. describes the earlier
10 versions of spray technology. United States Patent No. 6,108,201 entitled Fluid Control
11 Apparatus and Method for Spray Cooling to Tilton et al. also describes the usage of spray
12 technology to cool a printed circuit board. Spray thermal management may be performed
13 locally (i.e. where the chip is sprayed directly), globally (i.e. where the chip and
14 surrounding electronics/boards are also sprayed), a combination of locally and globally, or
15 in conjunction with air cooling or other cooling methods.

16

17 One problem with conventional spray technology is that excess coolant is often
18 times retained within the spray chamber to ensure adequate coolant return flow to the
19 pump and to compensate for any coolant leakage. This excess coolant can interfere
20 with the thermal management of electronic devices within the spray chamber. In
21 addition, this excess coolant can also directly impact and damage the electronic
22 components during attitude changes, deceleration and acceleration of the spray
23 chamber.

24

25 Another problem with conventional spray technology is that prior to accessing
26 the spray chamber the coolant must be drained which can lead to contamination and
27 coolant loss. A further problem with conventional spray technology is that during
28 acceleration, deceleration and attitude change, temporary coolant loss to the pump may
29 occur thereby decreasing the efficiency of the spray system. Another problem with

1 conventional spray technology is that the pressure within the spray chamber varies
2 greatly and is typically dependent solely upon the evaporation of coolant, volume of
3 coolant in spray chamber and temperature within the spray chamber without adequate
4 control. Another problem with conventional spray technology is that if a leak within
5 the spray system exists there is no automatic method for adding additional coolant to
6 the spray system to compensate for the coolant loss. A further problem with
7 conventional spray technology is that the seal of the spray chamber typically must be
8 broken to fill or add coolant.

9

10 While these devices may be suitable for the particular purpose to which they
11 address, they are not as suitable for increasing the efficiency and performance of a
12 spray thermal management system. In these respects, the spray coolant reservoir
13 system according to the present invention substantially departs from the conventional
14 concepts and designs of the prior art, and in so doing provides an apparatus primarily
15 developed for the purpose of increasing the efficiency and performance of a spray
16 thermal management system.

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2 **BRIEF SUMMARY OF THE INVENTION**
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4 In view of the foregoing disadvantages inherent in the known types of spray
5 thermal management systems now present in the prior art, the present invention
6 provides a new spray coolant reservoir system construction wherein the same can be
7 utilized for increasing the efficiency and performance of a spray thermal management
8 system.

9
10 The general purpose of the present invention, which will be described
11 subsequently in greater detail, is to provide a new spray coolant reservoir system that
12 has many of the advantages of the spray thermal management systems mentioned
13 heretofore and many novel features that result in a new spray coolant reservoir system
14 which is not anticipated, rendered obvious, suggested, or even implied by any of the
15 prior art spray thermal management systems, either alone or in any combination
16 thereof.

17
18 To attain this, the present invention generally comprises a reservoir capable of
19 storing a volume of coolant, a chassis with a spray chamber, a pump unit, an intake
20 valve fluidly connected to the pump unit for providing coolant from the reservoir or
21 the spray chamber, an output valve fluidly connected to the pump unit for controlling
22 coolant flow from the pump unit to either the spray unit or the reservoir. The reservoir
23 preferably includes a vent port, a fill port, and a chamber port. The chamber port is
24 fluidly connected to the spray chamber for allowing control of the internal pressure
25 within the spray chamber.

26
27 There has thus been outlined, rather broadly, the more important features of the
28 invention in order that the detailed description thereof may be better understood, and
29 in order that the present contribution to the art may be better appreciated. There are

1 additional features of the invention that will be described hereinafter and that will form
2 the subject matter of the claims appended hereto.

3

4 In this respect, before explaining at least one embodiment of the invention in
5 detail, it is to be understood that the invention is not limited in its application to the
6 details of construction and to the arrangements of the components set forth in the
7 following description or illustrated in the drawings. The invention is capable of other
8 embodiments and of being practiced and carried out in various ways. Also, it is to be
9 understood that the phraseology and terminology employed herein are for the purpose
10 of the description and should not be regarded as limiting.

11

12 A primary object of the present invention is to provide a spray coolant reservoir
13 system that will overcome the shortcomings of the prior art devices.

14

15 A second object is to provide a spray coolant reservoir system for increasing the
16 efficiency and performance of a spray thermal management system.

17

18 Another object is to provide a spray coolant reservoir system that provides
19 supplemental coolant to compensate for leaks within the spray thermal management
20 system.

21

22 An additional object is to provide a spray coolant reservoir system that is
23 capable of receiving the coolant drained from a spray chamber prior to opening the
24 spray chamber.

25

26 Another object is to provide a spray coolant reservoir system that does not
27 require opening of the spray chamber to fill or add coolant.

28

1 A further object is to provide a spray coolant reservoir system that provides an
2 auxiliary coolant supply for a coolant pump.

3

4 Another object is to provide a spray coolant reservoir system that ensures an
5 adequate coolant supply to the pump during acceleration, deceleration and attitude
6 changes.

7

8 Another object is to provide a spray coolant reservoir system that allows for
9 manipulation of the internal pressure of the spray chamber thereby controlling coolant
10 vaporization within the spray chamber.

11

12 A further object is to provide a spray coolant reservoir system that is capable of
13 creating a negative pressure within the spray chamber to reduce coolant leakage.

14

15 A further object is to provide a spray coolant reservoir system that prevents
16 excessive fluid retention within the spray chamber.

17

18 Another object is to provide a spray coolant reservoir system that allows an
19 individual to conveniently monitor the coolant level.

20

21 Other objects and advantages of the present invention will become obvious to the
22 reader and it is intended that these objects and advantages are within the scope of the
23 present invention.

24

25 To the accomplishment of the above and related objects, this invention may be
26 embodied in the form illustrated in the accompanying drawings, attention being called
27 to the fact, however, that the drawings are illustrative only, and that changes may be
28 made in the specific construction illustrated and described within the scope of the
29 appended claims.

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2 **BRIEF DESCRIPTION OF THE DRAWINGS**
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4 Various other objects, features and attendant advantages of the present
5 invention will become fully appreciated as the same becomes better understood when
6 considered in conjunction with the accompanying drawings, in which like reference
7 characters designate the same or similar parts throughout the several views, and
8 wherein:
9

10 FIG. 1 is a side cutaway view of the present invention with the reservoir within
11 the chassis.
12

13 FIG. 2 is a block diagram illustrating the fluid connections and coolant flow
14 within the present invention.
15

16 FIG. 3 is an upper perspective view of the present invention with an exposed
17 spray chamber and with the reservoir external of the chassis.
18

19 FIG. 4 is a side view of the present invention with an exposed spray chamber.
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21 FIG. 5 is an upper perspective view of the present invention with an exposed
22 spray chamber.
23

24 FIG. 6 is a side view of the present invention with an internal condenser within
25 the spray chamber.
26

27 FIG. 7 is a flowchart illustrating the coolant flow within the present invention.
28

1 FIG. 8 is a flowchart illustrating the process for reducing the spray chamber
2 pressure.

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4 FIG. 9 is a flowchart illustrating the process for increasing the spray chamber
5 pressure.

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7 FIG. 10 is a block diagram illustrating the electrical connections and
8 communications of the present invention.

9

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2 **DETAILED DESCRIPTION OF THE INVENTION**
3

4 **A. Overview**

5 Turning now descriptively to the drawings, in which similar reference
6 characters denote similar elements throughout the several views, FIGS. 1 through 10
7 illustrate a spray coolant reservoir system **10**, which comprises a reservoir **50** capable
8 of storing a volume of coolant, a chassis **20** with a spray chamber **22**, a pump unit **30**,
9 an intake valve **34** fluidly connected to the pump unit **30** for providing coolant from
10 the reservoir **50** or the spray chamber **22**, an output valve **36** fluidly connected to the
11 pump unit **30** for controlling coolant flow from the pump unit **30** to either the spray
12 unit **32** or the reservoir **50**. The reservoir **50** preferably includes a vent port **42**, a fill
13 port **46**, and a chamber port **44**. The chamber port **44** is fluidly connected to the spray
14 chamber **22** for allowing control of the internal pressure within the spray chamber **22**.
15

16 **B. Chassis**

17 As shown in Figures 1, 3 through 6 of the drawings, the chassis **20** may have
18 various shapes, structures and configurations. The chassis **20** illustrated in the
19 drawings should not be interpreted to limit the scope of protection of the present
20 invention. The chassis **20** may be freestanding or mounted into a rigid structure, such
21 as but not limited to a network rack.
22

23 The chassis **20** includes at least one spray chamber **22** as shown in Figures 1, 3
24 through 6 of the drawings. The spray chamber **22** is selectively sealed by a door or
25 panel structure which is well known in the art of spray technology.
26

27 The spray chamber **22** is designed to allow for liquid coolant to contact
28 electronic devices such as but not limited to electronic card members **12** thereby
29 conducting the thermal energy generated by the card members **12**. The card members

1 12 may be retained within a card cage 14 or similar structure for support and
2 protection. The card members 12 positioned within the spray chamber 22 must be
3 capable of being positioned within a dielectric coolant which is also well-known in
4 spray technology.

5

6 **C. Reservoir**

7 As Figures 1 through 6 illustrate, a reservoir 50 is provided within the present
8 invention. The reservoir 50 is capable of storing a volume of coolant and is fluidly
9 connected to the coolant system. The reservoir 50 is capable of receiving excess
10 coolant from the spray chamber 22. The reservoir 50 is also capable of providing
11 coolant to the spray chamber 22 when coolant levels within the spray chamber 22 fall
12 below a specified level.

13

14 Figure 1 illustrates the reservoir 50 within the chassis 20 or the spray chamber
15 22. However the reservoir 50 may be positioned external of the chassis 20 as shown in
16 Figures 3 through 6 of the drawings.

17

18 The reservoir 50 preferably includes a fill port 46 and a drain port 48. The fill
19 port 46 allows for selective filling of the reservoir 50 with coolant and the drain port
20 48 allows for selective draining of coolant from the reservoir 50.

21

22 The reservoir 50 preferably includes a vent port 42 as shown in Figures 1 and 3
23 of the drawings. The vent port 42 allows for the selective release of gas pressure
24 within the reservoir 50. The vent port 42 also allows for the selective entry of air into
25 the reservoir 50. During normal operation, the vent port 42 is preferably closed.

26

27 The reservoir 50 preferably includes a chamber port 44 fluidly connected to
28 spray chamber 22 as shown in Figures 1, 4, 5 and 6 of the drawings. When the
29 chamber port 44 is opened, the pressures within the spray chamber 22 and the reservoir

1 50 become equalized. During normal operation the chamber port 44 is preferably
2 closed.

3

4 **D. Coolant System**

5 The coolant system is fluidly connected to the spray unit 32, the spray chamber
6 22 and the reservoir 50. The coolant system preferably provides pressurized and
7 thermally managed coolant to the spray unit 32. U.S. Patent Nos. 5,220,804 and
8 6,108,201 illustrate spray technology that may be utilized within the present invention and
9 are hereby incorporated by reference into this application.

10

11 As shown in Figures 1 and 2 of the drawings, an intake valve 34 is fluidly
12 connected to the coolant system for providing coolant to the coolant system. The
13 intake valve 34 is also fluidly connected to the spray chamber 22 and to the reservoir
14 50 as further shown in Figures 1 and 2. A pickup valve 40 or similar device is
15 preferably positioned within the spray chamber 22 for drawing the waste coolant out of
16 the spray chamber 22 as shown in Figure 1 of the drawings.

17

18 The intake valve 34 diverts a coolant input flow to the coolant system from the
19 reservoir 50 when coolant flow from the spray chamber 22 is hindered as shown in
20 Figure 7 of the drawings. Coolant flow from the spray chamber 22 may be hindered
21 when there is no coolant flow or reduced coolant flow from the spray chamber 22 due
22 to various factors such as but not limited to acceleration, deceleration and attitude
23 change. The intake valve 34 preferably allows coolant input flow to the coolant
24 system solely from the spray chamber 22 during normal operation, and solely or jointly
25 from the reservoir 50 when coolant flow from the spray chamber 22 is hindered.

26

27 An output valve 36 is fluidly connected to the coolant system opposite of the
28 input valve as shown in Figures 1 and 2 of the drawings. The output valve 36 is
29 fluidly connected to the spray unit 32 and to the reservoir 50 for providing pressurized

1 fluid from the coolant system to the same. The output valve 36 preferably allows
2 coolant output flow solely to the spray unit 32 from the coolant system during normal
3 operation. However, when excess coolant is present within the spray chamber 22, the
4 output valve 36 may divert the coolant output flow to the reservoir 50 to fill the
5 reservoir 50.

6
7 As shown in Figures 1 and 2 of the drawings, the coolant system preferably
8 includes a pump unit 30 that is fluidly connected between the intake valve 34 and the
9 output valve 36. The pump unit 30 may be comprised of various well-known pump
10 technologies.

11
12 A condenser 60 is also preferably provided that may be positioned internally or
13 externally of the spray chamber 22 for condensing vaporized coolant. The condenser
14 60 is connected to a heat exchanger 70 which reduces the temperature of the condenser
15 60 which is well known in the art. Filters, thermal management units and related
16 devices may also be included within the coolant system though not shown in the
17 drawings.

18 19 *E. Control Unit*

20 As shown in Figure 10 of the drawings, a control unit 38 is provided that is in
21 communication with the coolant system, the pump unit 30, the intake valve 34, the
22 output valve 36, the pickup valve 40, the vent port 42, the drain port 48, the fill port
23 46, the chamber port 44, the heat exchanger 70, the condenser 60, the sensors 39 and
24 any other related electronic device. The sensors 39 are capable of measuring various
25 conditions such as but not limited to coolant temperature, electronic device
26 temperature, coolant levels (in spray chamber 22 and in the reservoir 50), coolant flow,
27 pressure (in spray chamber 22 and in the reservoir 50), the attitude of the chassis 20
28 and other related conditions.

1 The control unit 38 may be comprised of various electronic technologies such
2 as but not limited to computer devices. The control unit 38 is preferably
3 programmable and capable of receiving and transmitting data. More than one control
4 unit 38 may be utilized with the present invention. In addition, some of the devices
5 within the present invention may be in direct or indirect communication with one
6 another.

7

8 ***F. Controlling Coolant Flow***

9 As shown in Figure 7 of the drawings, the coolant is first drawn from the spray
10 chamber 22 to provide a supply coolant flow to the spray unit 32. However, if the
11 coolant flow from the spray chamber 22 is hindered (e.g. stopped or reduced), then the
12 coolant is drawn from the reservoir 50 until coolant flow from the spray chamber 22 is
13 no longer hindered as shown in Figure 7 of the drawings. It is preferably to terminate
14 the coolant flow from the spray chamber 22 when drawing coolant from the reservoir
15 50, however the coolant may be drawn simultaneously from both the reservoir 50 and
16 the spray chamber 22.

17

18 If the spray chamber 22 has excess coolant, it is desirable to divert all or a
19 portion of the coolant flow from the pump unit 30 to the reservoir 50 by the output
20 valve 36 until a desired coolant level is achieved within the spray chamber 22.
21 Alternatively, if the coolant level within the spray chamber 22 falls below a desired
22 level (e.g. leakage problems), all or a portion of the coolant drawn into the pump may
23 be supplied by the reservoir 50 by the intake valve 34.

24

25 ***G. Controlling Spray Chamber Pressure***

26 ***1. Overview***

27 It is desirable to control the pressure within the spray chamber 22 for various
28 reasons. For example, a negative or reduced pressure within the spray chamber 22 will

1 prevent leakage through a damaged seal. Also, increased pressure within the spray
2 chamber **22** facilitates condensing of the coolant at higher temperatures.

3 4 **2. Reducing Spray Chamber Pressure**

5 Figure 8 illustrates an exemplary process for reducing the pressure within the
6 spray chamber **22**. First, the chamber port **44** is closed if not already closed. Second,
7 the vent port **42** is then opened and the intake valve **34** is switched to draw fluid only
8 from the pickup valve **40** within the spray chamber **22**. Next, the output valve **36** is
9 switched to provide pressurized coolant from the pump unit **30** solely to the reservoir
10 **50** only.

11
12 The pump unit **30** is then operated which draws coolant from within the spray
13 chamber **22** and forcing the fluid into the reservoir **50**. As the coolant is drawn out of
14 the spray chamber **22**, the pressure within the spray chamber **22** is reduced (even to the
15 level of negative pressure). As the coolant is forced into the reservoir **50**, the vent port
16 **42** allows the displaced gases within the reservoir **50** to escape into the atmosphere or
17 other structure. The vent port **42** also prevents an increase in the pressure of the
18 reservoir **50** during this process.

19
20 Once the desired reduced pressure within the spray chamber **22** has been
21 achieved, the pump unit **30** is terminated and the vent port **42** is closed as shown in
22 Figure 8 of the drawings. The chamber port **44** is then opened to allow for
23 equalization of the pressures within the spray chamber **22** and the reservoir **50** as
24 further shown in Figure 8 of the drawings.

25
26 If the coolant level within the spray chamber **22** has dropped below a desired
27 level, coolant from the reservoir **50** may be input back into the spray chamber **22** with
28 the chamber port **44** open to prevent an increase in pressure within the spray chamber

22 or without the chamber port 44 open. The chamber port 44 may then be closed to allow for normal operation of the present invention.

3. *Increasing Spray Chamber Pressure*

Figure 9 illustrates an exemplary process for increasing the pressure within the spray chamber 22. First, the chamber port 44 is closed if not already closed. Second, the vent port 42 is then opened and the intake valve 34 is switched to draw fluid only from the reservoir 50 only. Next, the output valve 36 is switched to provide pressurized coolant from the pump unit 30 solely to the spray chamber 22 only. The coolant may be provided into the spray chamber 22 via the spray unit 32 or a direct port.

The pump unit 30 is then operated which draws coolant from within the reservoir 50 and forcing the fluid into the spray chamber 22. As the coolant is forced into the spray chamber 22, the pressure within the spray chamber 22 is increased. As the coolant is forced into the spray chamber 22, the vent port 42 allows for air to enter the reservoir 50 to displace the reduced coolant thereby preventing a reduced pressure within the reservoir 50.

Once the desired increased pressure within the spray chamber 22 has been achieved, the pump unit 30 is terminated and the vent port 42 is closed as shown in Figure 9 of the drawings. The chamber port 44 is then opened to allow for equalization of the pressures within the spray chamber 22 and the reservoir 50 as further shown in Figure 9 of the drawings.

If the coolant level within the spray chamber 22 has increased above a desired level, coolant from the spray chamber 22 may be input back into the reservoir 50 with the chamber port 44 open to prevent a decrease in pressure within the spray chamber

1 22 or without the chamber port 44 open. The chamber port 44 may then be closed to
2 allow for normal operation of the present invention.

3

4 As to a further discussion of the manner of usage and operation of the present
5 invention, the same should be apparent from the above description. Accordingly, no
6 further discussion relating to the manner of usage and operation will be provided.

7

8 With respect to the above description then, it is to be realized that the optimum
9 dimensional relationships for the parts of the invention, to include variations in size,
10 materials, shape, form, function and manner of operation, assembly and use, are
11 deemed to be within the expertise of those skilled in the art, and all equivalent
12 structural variations and relationships to those illustrated in the drawings and
13 described in the specification are intended to be encompassed by the present invention.

14

15 Therefore, the foregoing is considered as illustrative only of the principles of
16 the invention. Further, since numerous modifications and changes will readily occur to
17 those skilled in the art, it is not desired to limit the invention to the exact construction
18 and operation shown and described, and accordingly, all suitable modifications and
19 equivalents may be resorted to, falling within the scope of the invention.